4

Current and Historical Status of River and Stream Ecosystems

Aquatic ecosystems of the Klamath River basin have been extensively modified by human activities that have changed hydrology and channel morphology, increased fluxes of nutrients, increased erosion, introduced exotic species, and changed water temperatures. Efforts at restoration of declining native species need to recognize the unique characteristics of various portions of the basin in the current context of land use and human activities. This chapter considers the major streams and rivers of the Klamath basin and analyzes anthropogenic changes in conditions that affect especially the coho salmon and endangered suckers but also other fishes and aquatic life generally. Each section of this chapter considers either a specific section of the mainstem Klamath River or of its tributaries; locations are designated in river mi (RM) from the ocean.

TRIBUTARIES TO UPPER KLAMATH LAKE (RM 337-270)

Streams and rivers above Upper Klamath Lake are a source of nutrients to the lake and provide spawning and larval habitat for endangered suckers. The main sources of surface water for Upper Klamath Lake are the Williamson, Sprague, and Wood rivers (Kann and Walker 2001; Chapter 2). Ground water and direct precipitation account for most of the balance of inflow.

For Upper Klamath Lake, external loading of phosphorus, a key nutrient that promotes algal blooms (Chapter 3), comes primarily from the Williamson, Sprague, and Wood drainages. Geologic features of this region cause its streams and rivers to carry naturally high phosphorus loads (Chapter 3). Background concentrations of phosphorus, however, are augmented by human activity related to land use and river modifications. The Williamson and Sprague watersheds contribute 86 metric tons of phosphorus to Upper Klamath Lake per year (Kann and Walker 2001). The Williamson accounts for 21% of the total load, and the Sprague accounts for 27% (Figure 4-1).

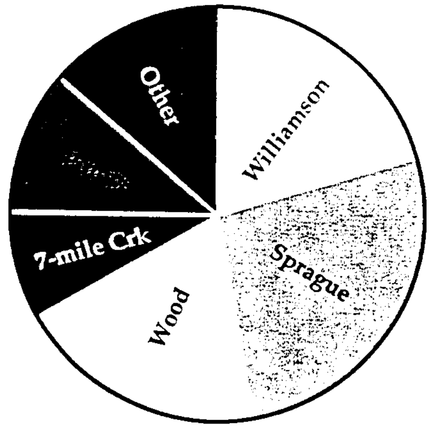


Figure 4-1. Relative external phosphorus loading from tributaries and other sources to Upper Klamath Lake. Source: data from Kann and Walker 2001.

Recent changes in hydrology may have affected total nutrient loading of Upper Klamath Lake. Annual runoff from the Williamson and Sprague drainages increased from the period 1922-1950 to the period 1951-1996 (Risley and Laenen 1999). The cause of the change is uncertain, but it is independent of climatic variability and probably is related to a combination of river channelization, reduction in area of wetlands, timber harvest, and other factors that reduce evapotranspiration in the watershed (Risley and Laenen 1999). Increased flows from the Williamson and Sprague drainages, coupled with current land-use practices, probably have increased phosphorus transport within the basin through greater erosion that leads to higher transport of suspended sediments, which carry phosphorus. Estimates of sedimentation rates from cores taken in Upper Klamath Lake support the hypothesis that transport of sediments from the watershed has increased in recent decades (Eilers et al. 2001).

Although its watershed is much smaller than that of the Williamson River, the Wood River is an important phosphorus source and has a high export of phosphorus per unit area of watershed (Figure 4-1). The balance of the phosphorus load to Upper Klamath Lake comes from Seven Mile Creek, agricultural pumps, and miscellaneous sources. Virtually all of this phosphorus is from nonpoint sources, including both natural and anthropogenic components.

Rivers and streams above Upper Klamath Lake support populations of coldwater fishes, including Klamath redband and bull trout (Chapter 5). During summer, temperatures can be undesirably high for these fishes in many stream reaches. For example, one threshold temperature that is used by government agencies to assess suitable rearing habitat for coldwater fishes is 17.8°C. The Williamson and especially the Sprague during late summer exceed this temperature (Boyd et al. 2001). In addition, concentrations of dissolved oxygen in the main stem of the Sprague River (mouth to junction of the North and South Forks) fall below Environmental Protection Agency water-quality targets (Boyd et al. 2002). Modeling indicates that restoration of riparian vegetation potentially could reduce temperatures in the Sprague through shading (Boyd et al. 2002), and also could have a beneficial effect on oxygen concentrations because water holds more dissolved oxygen at low temperatures than at high temperatures. In addition, shading could reduce the accumulation of algae and rooted aquatic plants on the sides and beds of tributaries. Plants produce oxygen through photosynthesis and thereby potentially increased concentrations of dissolved oxygen during the day, but nocturnal respiration and the degradation of accumulations of nonliving organic matter that they produce can cause oxygen depletion. Hence, temperature management via restoration of shading may help to alleviate a number of water-quality problems. Water-quality problems in the streams are less likely to affect endangered suckers than some of the other native fishes, however (Chapter 5).

Efforts are underway to restore wetlands associated with the Williamson, Wood, and Sprague rivers. The rationale for the projects is to restore wetland-river connections that promote such processes as nutrient trapping and sediment retention, to provide habitat for young fish, and to damp variations in river flow. Wetlands are sources of dissolved organic matter and tend to enrich water with complex humic compounds that may be related to changes in the composition of phytoplankton blooms observed in Upper Klamath Lake (Chapter 3).

THE LOST RIVER

The Lost River main stem (Figure 1-3) was an important spawning site for suckers and supported a major fishery, but few suckers use the river now (Chapter 5). Water that historically would have entered the Lost River from October to April is held back by Gerber and Clear Lake dams; summer flows are reduced by withdrawals and are dominated by irrigation tailwater. Free interchange of water and fish with the Klamath main stem is blocked in various ways. Not surprisingly, water quality of the Lost River is poor throughout the year, as indicated by low oxygen concentrations and high concentrations of suspended solids (Shively et al. 2000a, USFWS 2001), and physical habitat is greatly changed from its original state. The Lost River is now so degraded that restoration of conditions suitable for sucker spawning seems unlikely unless land-use or water-management practices change.

THE MAINSTEM KLAMATH: IRON GATE DAM TO ORLEANS (RM 192-60)

Below Iron Gate Dam, the Klamath River runs unobstructed to the ocean. Alterations in flow and high temperatures make conditions in the mainstem Klamath less suitable than was the case historically for salmonids that use the river for spawning, rearing, and migration (Chapter 7). Four major tributaries (the Shasta, Scott, Salmon, and Trinity rivers) enter the Klamath main stem below Iron Gate Dam. These are considered in detail below.

The effect of management on the annual cycle of water flow has been the subject of considerable research on historical flows in the main stem. Before the creation of the Klamath Project and other modifications of flow, the Klamath River had a relatively smooth annual hydrograph with high flows in winter and spring that declined gradually during summer and recovered in fall. This pattern reflects the seasonal cycle of winter rainfall and spring rainfall and snowmelt in the basin (Risley and Laenen 1999). There is still an annual cycle, but its magnitude and seasonal dynamics have changed (Hardy and Addley 2001).

Figure 4-2 illustrates hydrologic change on the basis of a comparison of mean monthly flows for the periods 1905-1912 (pre-project) and 1961-1996 (post-project). Data on the earlier period are estimates based on measured discharges at the Keno gaging site extrapolated to discharges for the Iron Gate Dam site; data on the later period are based on direct measurements at the Iron Gate Dam (for methods, see USGS, Fort Collins, CO, unpublished material, 1995; Balance Hydrologics 1996; Hardy and Addley 2001). Flows over the period 1905-1912 have been adjusted to correct for the above-average precipitation that occurred then.

Post-project flows exhibit a shift in peak annual runoff from a mean maximum centered on April to a mean maximum centered on March (Figure 4-2). The later recession in spring flows extends to mean minimum flows lower than the historical minimums. Low-flow conditions during summer are more prolonged than they were before the project was built. The same analyses indicate that post-project flows during fall are slightly higher than pre-project flows. The annual volume of flow from the upper Klamath basin is probably reduced. Estimated average annual runoff at the Iron Gate Dam site has declined by about 370,000 acre-ft since the construction of the Klamath Project (Balance Hydrologics 1996), as might be expected in view of the amount of water that is used for irrigation above Iron Gate Dam (Table 1-1). The magnitude of the change in water yield is a matter of dispute among groups concerned with water use in the upper basin. Nevertheless, there is no doubt that changes in seasonality of flow and at least some change in water yield have occurred since the full development of the Klamath Project.

As noted by the U.S. Geological Survey (USGS, Fort Collins, Colorado, unpublished material 1995) in its review of the hydrology of the Klamath River, the changes in flow below Iron Gate Dam are attributable to water-management practices in the upper and lower Klamath basin. The shift toward an earlier peak in annual runoff appears to be associated with increased flows in the Klamath River from the Lost River diversions and the loss of seasonal hydrologic buffering that originally was associated with overflow into Lower Klamath Lake and Tule Lake. The persistent low-flow conditions that occur in summer below Iron Gate Dam reflect irrigation demand in the Klamath Project and other parts of the upper Klamath basin and irrigation diversions on the Scott and Shasta rivers and other tributaries (discussion below).

Release of water from Iron Gate Dam has both direct and indirect effects on water temperature in the Klamath River. The magnitude of these effects depends on three principal factors: the temperature of the water as it is released from the dam, the volume of the release, and the meteorological conditions. The temperature of water released from Iron Gate Dam varies seasonally; a peak at about 22°C (+/- 2°C) occurs in August (Figure 4-3). In summer, the volume of flow exerts substantial control over the rate of daytime warming and nocturnal cooling. Low flows have long transit times and thus show greater change per unit distance. For example, a 500-cfs release takes 2.5 days to reach Seiad Valley, a distance of about 60 river mi, whereas a 1000-cfs release moves the same distance in 2 days and a 3000-cfs release does so in 1.25 days (Deas 2000). Warming and cooling per unit distance are reduced by short transit time and by greater depth. Higher flows extend the reach of river below Iron Gate Dam that supports lower mean water temperatures (Figure 4-4), but also may result in higher daily minimum temperatures over a portion of the reach below Iron Gate Dam (see below).

Increased releases from Iron Gate Dam may benefit coho salmon (Hardy and Addley 2001, NMFS 2001). The potential benefit from the releases is confounded, however, by

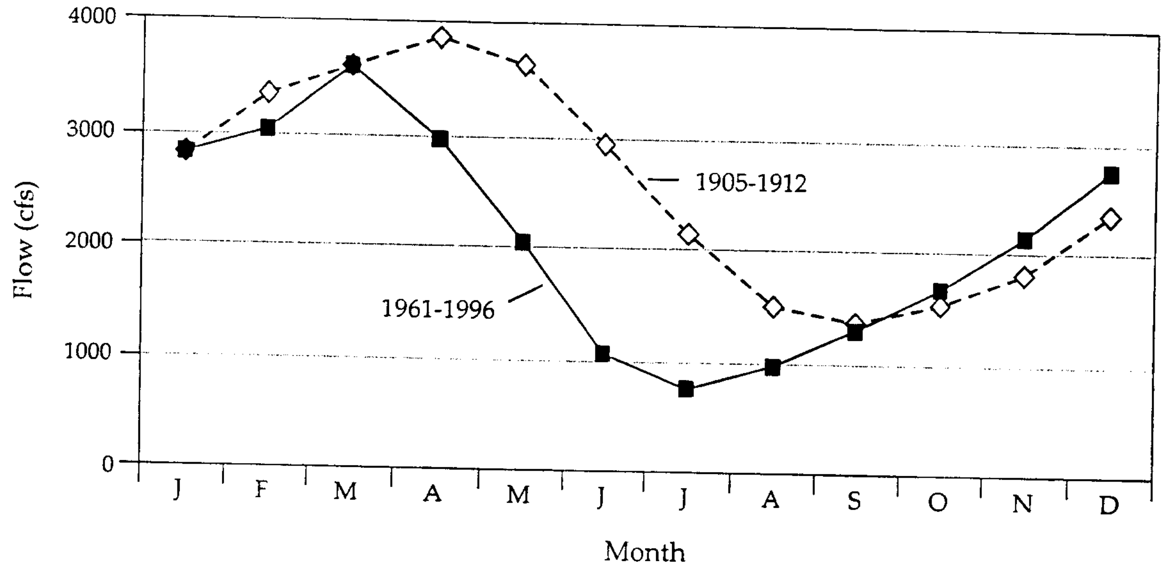


Figure 4-2. Mean monthly flows at Iron Gate Dam in 1961-1996 compared with reconstructed flows for 1905-1912. Source: data from Hardy and Addley 2001.

relationships between minimum, mean, and maximum temperatures. For example, water released from Iron Gate Dam in August has a mean temperature near 22°C, which is well above the acute tolerance threshold for coho (Chapters 7 and 8). Field-calibrated models developed by Deas (2000) and models presented by Hardy and Addley (2001) show a considerable increase in the daily mean water temperature with distance downstream for flows that are typical of August. As noted in Chapters 7 and 8, however, bioenergetics of salmonids depend not only on the mean temperature but also on the diel range of temperature; low minimum temperatures are especially important for coho salmon.

Simulations conducted by Deas (2000) provide insight into the thermal response of the Klamath River to increases in flow during late summer (Figure 4-4). Under moderate flow conditions in mid-August (1000 cfs), with typical accretions from tributaries, maximum daily temperatures increase rapidly downstream of Iron Gate Dam to a peak of 26°C within 15 mi. Daily minimum temperatures caused by nocturnal cooling reach a minimum of 20°C within about the same distance. By the time this water reaches Seiad Valley (RM 130), maximums are greater than 26°C, and minimums are 22°C; the average gain from Iron Gate Dam is 2°C. Tripling the flow from Iron Gate Dam (Figure 4-4B) provides modest reduction in mean and maximum daily temperatures, particularly in the first 20 mi of the river downstream from the dam. The increased volume of water and shorter transit time, however, reduce the effect of nocturnal cooling in the reach between Iron Gate Dam and Seiad, and raise minimum temperatures for about two-thirds of the reach. Although increased flows reduce mean and maximum temperatures, the increase in minimum temperatures may adversely affect fish that are at their limits of thermal tolerance (Chapters 7 and 8).

Two additional complications arise from increased releases from Iron Gate Dam. First, during low-flow conditions, tributaries can influence mainstem temperatures. Temperatures in

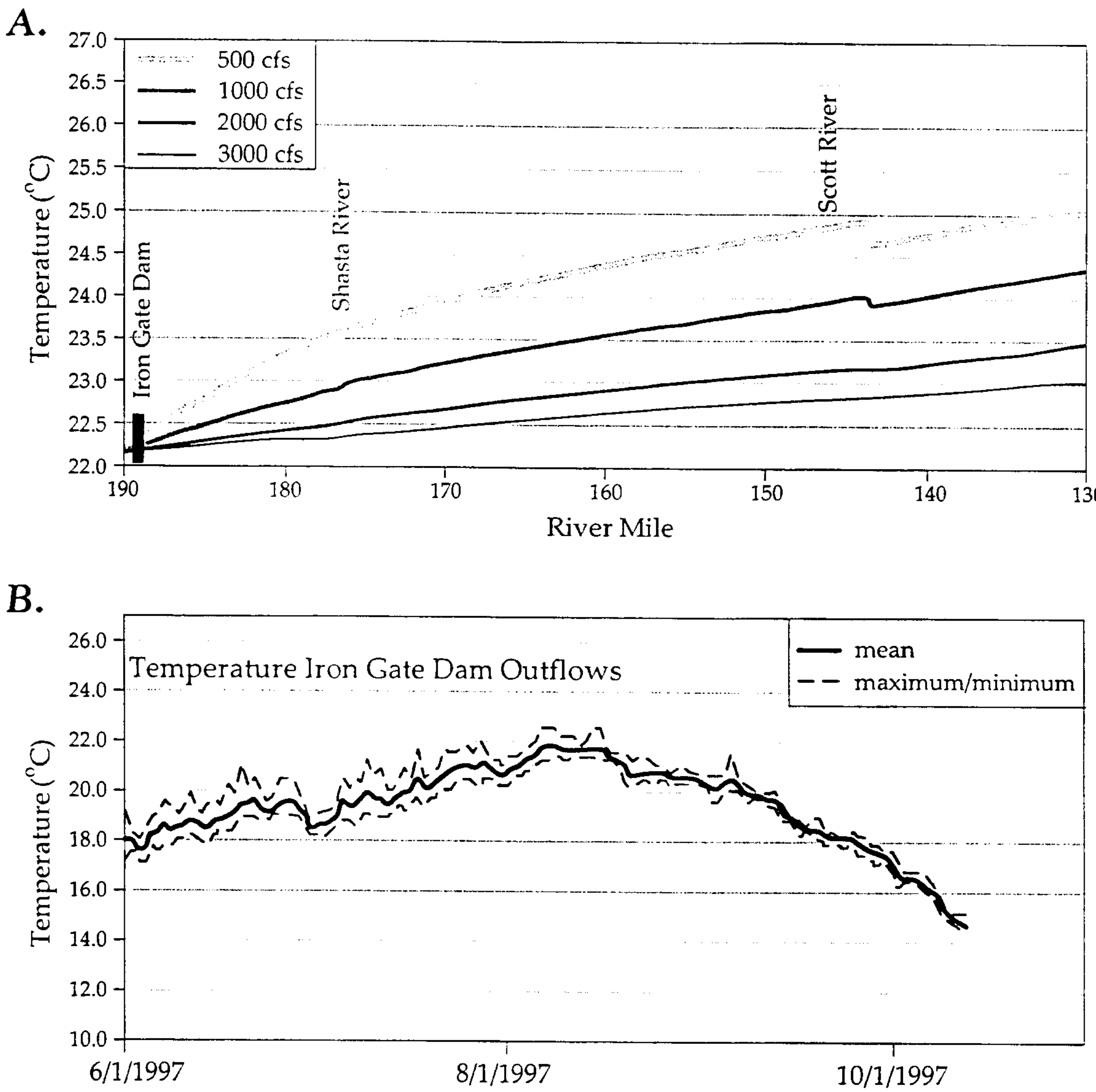


Figure 4-3. Simulated and measured temperature in the Klamath River below Iron Gate Dam. A) Simulated daily mean temperatures from Iron Gate Dam to Seiad Valley for flows of 500-3000 cfs for conditions in August. B) Measured temperature of releases from Iron Gate Dam, June-October 1997. Note the minor diel change in temperature during the warmest summer releases. Source: Deas 2000, permission pending.

the Klamath River at 1000 cfs are affected substantially by the Scott River and minimally by the Shasta River. Modification of flow and temperature regimes in these tributaries through better water management could improve mainstem temperatures. Increase in flow to 3000 cfs, however, eliminates any thermal benefit from the tributaries (Deas 2000).

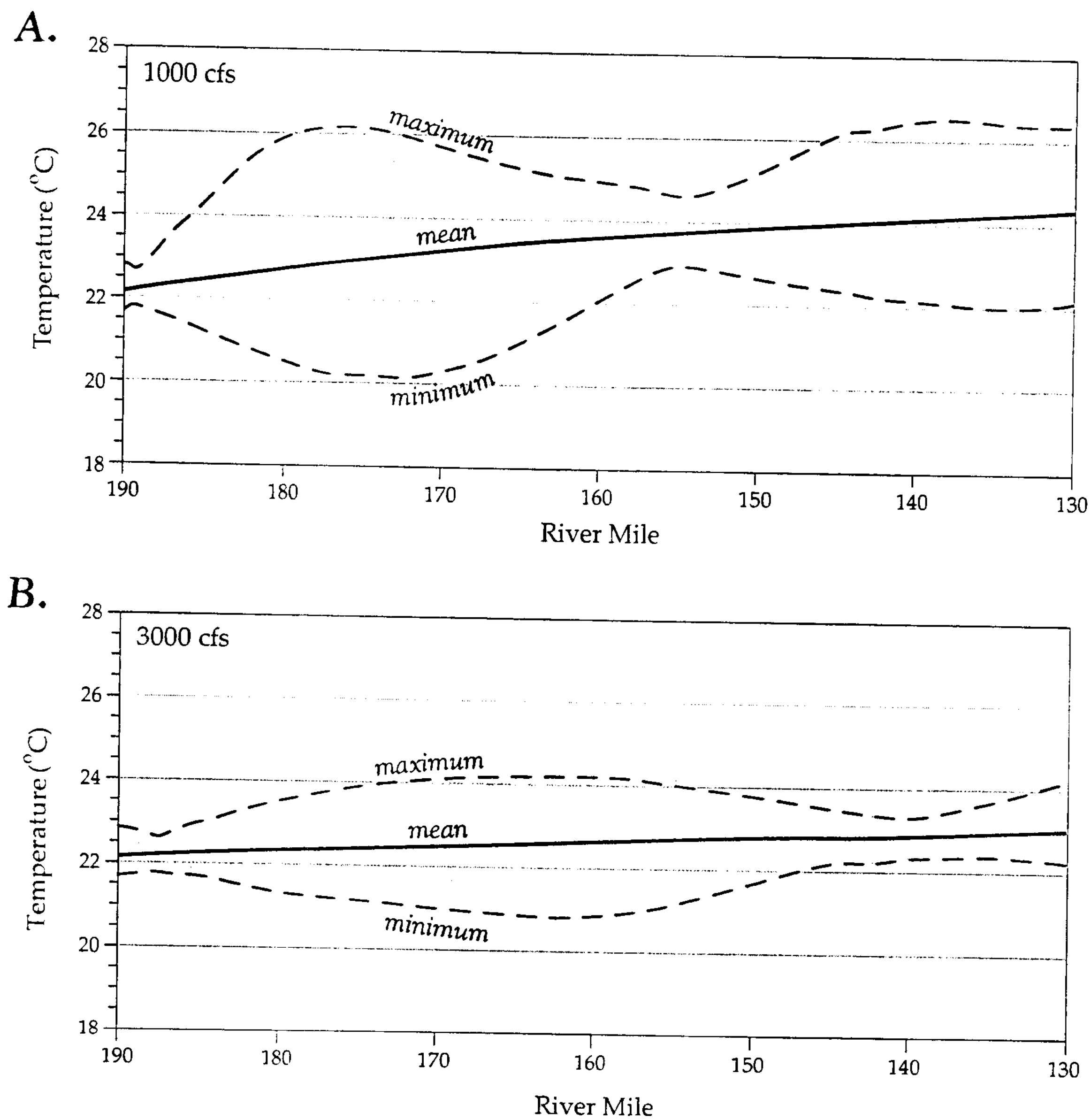


Figure 4-4. Simulated daily maximum, mean, and minimum water temperatures on the Klamath River from Iron Gate Dam to Seiad Valley for Iron Gate Dam releases of 1000 cfs (A) and 3000 cfs (B) under meteorological conditions of August 14, 1996. Source: Deas 2000, permission pending.

In regulated rivers such as the Klamath, there often is a node of minimum diel temperature variation about 1 day's travel time from a dam (Lowney 2000) and an antinode of maximum variation at half this distance. The muted minimums and maximums of the thermal node reflect a single diel cycle of roughly equal heating and cooling during 1 day's travel time. Conversely, the large variation in temperatures at the antinode reflects only half a diel heating or cooling cycle. Reduction in maximum temperature is one of the benefits of the thermal nodes.

These nodes, however, also exhibit greatly increased minimum temperatures. In the Klamath River under flow and meteorological conditions typical of August, the highest minimum daily temperatures will occur at the node and may be points of greatest thermal stress for salmonids. Increases in flow will cause the node to shift downstream because of decreased transit times (Figure 4-4), thus increasing the amount of river that is subjected to increased temperature minimums.

The mainstem Klamath—like the lakes, reservoirs, and rivers of the upper basin—has concentrations of nitrogen and phosphorus that are quite high relative to many aquatic systems (Campbell 2001, Figure 4-5); they indicate eutrophic conditions. In addition, much of the nitrogen and phosphorus is readily available for plant uptake (for example, the forms nitrate and soluble reactive phosphorus). As a consequence of high nutrient concentrations, the river has the potential to support high rates of primary production. Even when nutrient concentrations are high, however, blooms of phytoplankton, such as those in Upper Klamath Lake, do not occur in streams or rivers of moderate to high velocity because flow limits the accumulation of suspended algae. Conditions may be favorable in the main stem for the growth of phytoplankton during low flow, when the water is moving slowly, and growth of attached algae and aquatic vascular plants also can be stimulated by nutrients. Stimulation of any kind of plant growth can affect oxygen concentrations.

During summer, oxygen concentrations in the Klamath River often fall below 7 mg/L and, for brief periods, below 5.5 mg/L (Campbell 2001). For example, average concentrations were below 7 mg/L on 36 days at the Seiad Valley monitoring station in 1998. More severe and extended periods of low oxygen concentrations occur at Iron Gate Dam because of degradable organic matter (such as dead phytoplankton) originating in reservoirs. Low oxygen concentrations, especially below 5.5 mg/L, are unfavorable to salmonids (Chapter 7).

THE SHASTA RIVER (RM 177)

Flow of the Shasta River is dominated by discharge from numerous cool-water springs and not by surface runoff. The stable, cool flows and high fertility of the Shasta historically created a highly productive, thermally optimal habitat for salmonids.

The Shasta River maintains about 35 mi of fall-run Chinook habitat, 38 mi of coho habitat, and 55 mi of steelhead habitat (West et al. 1990). The amount of habitat has not declined since 1955 but is substantially smaller than the original amount. Use of remaining habitat is contingent on flow and water quality, both of which may be inadequate in dry years. Mean annual runoff from the Shasta River is 136,000 acre-ft, which is less than 1% of the runoff of the Klamath River at Orleans. Runoff within the basin peaks during winter, when daily flow is near 200 cfs (Figure 4-6). Peaks are associated with rain at times when there are no irrigation diversions (note that peaks did not occur in 2001, a year of drought). Flow declines rapidly with the onset of irrigation in late March. Flow minimums typically averaging less than 30 cfs occur during summer. Flow increases rapidly in the fall when irrigation ends. Winter base-flow conditions typically are 180-200 cfs, regardless of precipitation.

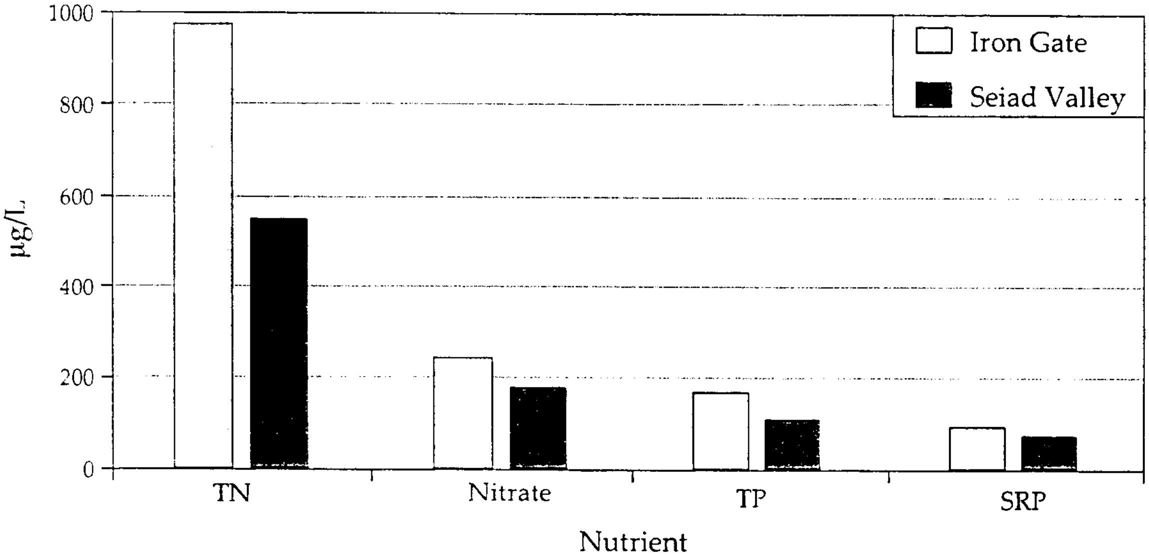


Figure 4-5. Mean annual concentrations of total nitrogen (TN) and total phosphorus (TP), nitrate (NO_3^- expressed as N), and soluble reactive phosphorus (SRP) at two stations on the Klamath River. Source: data from Campbell 2001.

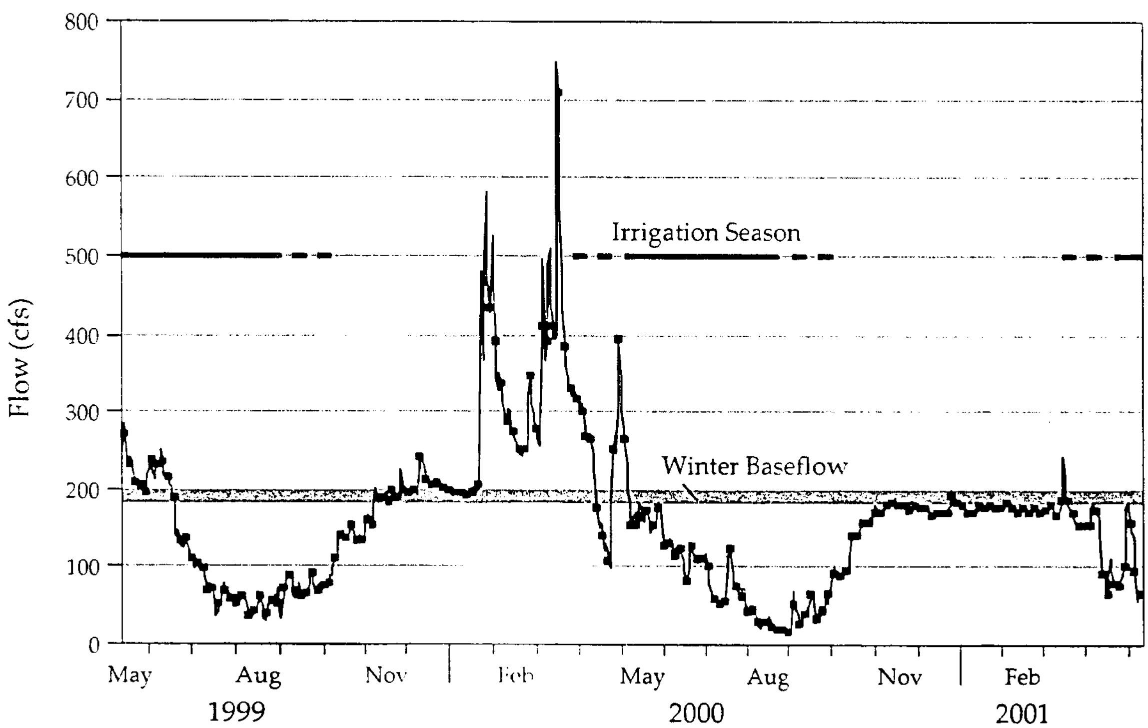


Figure 4-6. Annual hydrograph for the lower Shasta River (at Yreka, California), from May 1999 to May 2001. Note base-flow recovery during fall and sustained base flow throughout the winter of 2001.

The hydrology of the Shasta River is affected by surface-water diversions, alluvial pumping, and the Dwinnell Dam (Figure 4-7). Historically, springs and seeps dominated the hydrograph of the Shasta River. Mack (1960) reported that one small tributary, Big Springs (Figure 4-7), supplied a consistent 103 cfs to the Shasta River before water development. Flow from the springs and numerous small accretions in the reach above them would have supplied flows close to or exceeding today's bankfull condition, even during summer months. Flows of that magnitude would have had very short transit times (less than 1 day to the Klamath River), thus maintaining cool water throughout summer for the entire river. Consistency of flow and cool summer water were the principal reasons that the Shasta River was historically highly productive of salmonids. During summer, the Shasta River may also have cooled the mainstem Klamath near the confluence of the Shasta and the main stem.

Since 1932, surface-water resources in the Shasta valley have been under statutory adjudication (Decree 7035). Three of the four major irrigation districts have a cumulative appropriative right to divert more than 110 cfs from the Shasta River from April 1 to October 1 (Gwynne 1993). Dwinnell Dam is used by the fourth major irrigation district to store winter flows of the Shasta River and Parks Creek. Dwinnell Dam, constructed in 1928, has a capacity of 50,000 acre-ft. The California Department of Water Resources Watermaster Service has been apportioning water within the basin since 1934. Riparian water rights below Dwinnell Dam are not adjudicated and are not regulated by the watermaster, and the 1932 adjudication did not address ground water, which is critical for support of base flow.

Seven major diversion dams and numerous smaller dams or weirs are on the Shasta River and its tributaries below Dwinnell Dam (Figure 4-7). When the diversions are in operation, they substantially and rapidly reduce flows in the main stem (Figure 4-6). During the drought of 1992, flows in the Shasta dropped from 105 cfs on March 31 to 21 cfs by April 5. The numerous diversions on the Little Shasta River now routinely lead to complete dewatering of its channel in late summer. Although surface diversions play an important role in causing the low flows of the Shasta, there is little quantitative information on the relative role of each diversion, and records either have not been kept or are not available from the watermaster service that apportions flows.

Dwinnell Dam affects the hydropattern of the Shasta River. Peak winter flows associated with large precipitation events have been strongly suppressed. Absence of flushing flows reduces sediment transport and reduces the availability of spawning gravels downstream of the dam (Ricker 1997). With the exception of above-average water years, when Lake Shastina is full, no flow is released from Dwinnell Dam except for small amounts to specific water users downstream. Water in Parks Creek is diverted into Lake Shastina, thus decreasing winter flows in the creek. In addition, seepage losses from Lake Shastina are large; they exceed the total amount of water supplied to irrigators (Dong et al. 1974).

Ground water is not part of the adjudication of water rights in the Shasta basin, and little is known about its influence on surface flows. The exceptionally high specific capacity of the aquifers and the large recharge area make ground water one of the most important and resilient resources in the valley. Well records of the California Department of Water Resources (CDWR) indicate a great increase in the number of irrigation wells in the valley since the 1970s. The shift toward groundwater production from use of surface diversions may have had a measurable effect on surface flows and may have exacerbated low-flow conditions. For example, the Big Springs Irrigation District ceased using surface diversions and switched to groundwater wells in the

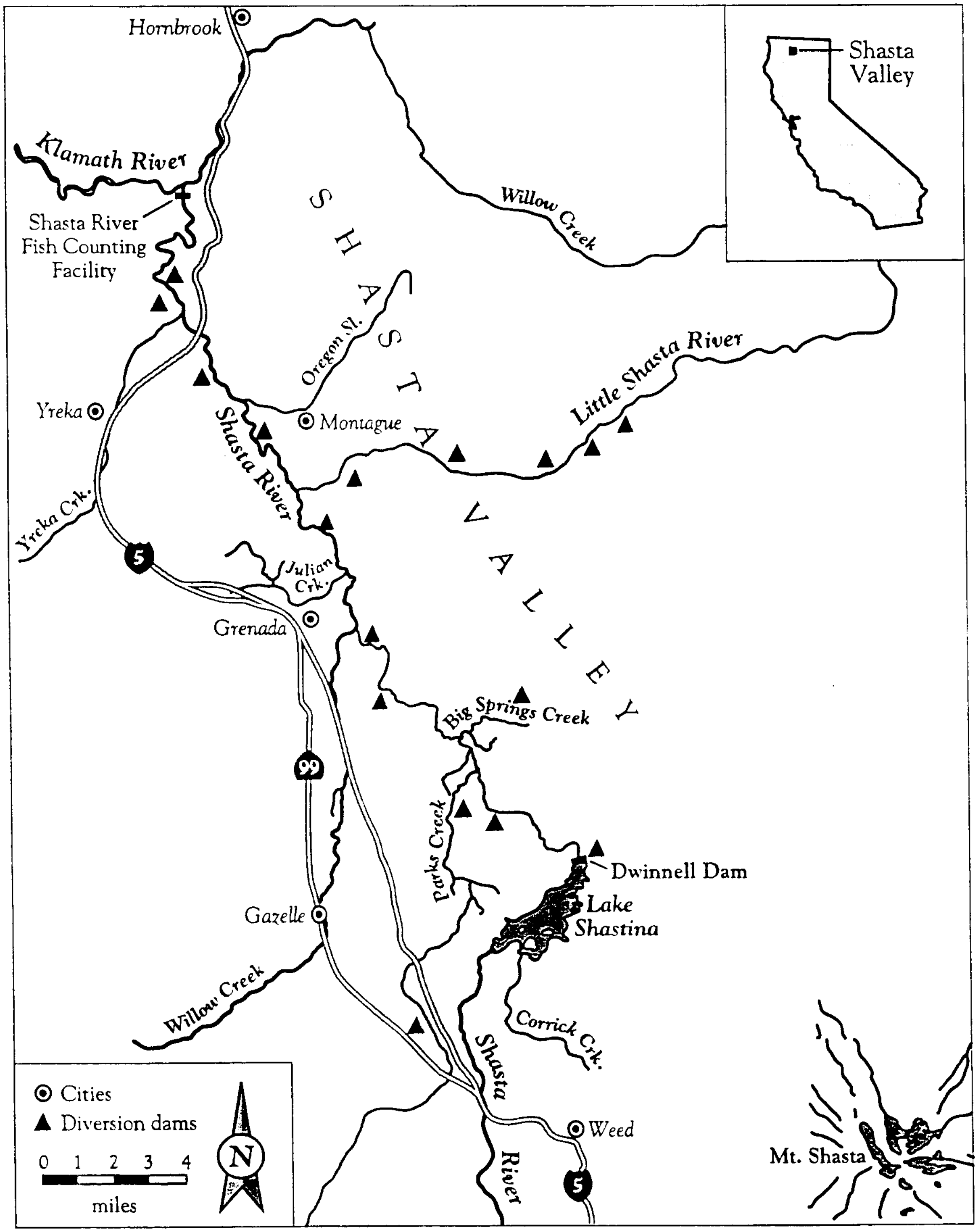


Figure 4-7. Map depicting substantial water diversions from the Shasta River below Dwinnell Dam. Note that the Shasta River flows north and drains into the Klamath River. Source: modified from Gwynne 1993.

1980s to meet its water needs; these highly productive wells may have contributed to the reported dewatering of the springs that historically fed Big Springs Creek.

Recent surveys have shown that channel conditions in the main stem of the Shasta River and its most important tributary, Parks Creek, generally are poor and may limit salmonid production. Replicate habitat surveys summarized by Ricker (1997) and Jong (1997) focus on Chinook spawning gravels and indicate that the percentage of fines in gravels is high throughout the main stem and Parks Creek. The fines, which are detrimental to egg survival and emergence of fry, are associated with accelerated erosion and lack of flushing flows that maintain and recruit coarse gravels.

In some reaches, particularly in the lower canyon and the reach below the Dwinnell Dam, limited recruitment of coarse gravels is contributing to a decline in abundance of spawning gravels (Buer 1981). The causes of the decline in gravels include gravel trapping by Dwinnell Dam and other diversions, bank-stabilization efforts, and historical gravel mining in the channel.

Loss of vegetation in the riparian corridor poses a widespread and important threat to salmonid habitat. In the lowermost reach of the Shasta River, the loss is explained principally by mining. In the valley above the lower Shasta, grazing has been responsible for most of the loss. Where intense unfenced grazing has occurred, trampling and removal of vegetation have commonly led to accelerated bank erosion, loss of shading, reduced accumulation of local woody debris, loss of pool habitat to sedimentation, loss of channel complexity and cover, and degradation of water quality. Riparian fencing programs and construction of stock-water access points are under way in the Shasta valley, but efforts to date are modest (Kier Associates 1999).

The Shasta River contains seven major diversion dams and multiple smaller dams or weirs (Figure 4-7). Dwinnell Dam eliminated access to about 22% of habitat historically available to salmon and steelhead in the watershed (Wales 1951). The reach between Big Springs and Dwinnell Dam, which has the potential to support a range of salmonids, receives minimal flows from the dam.

Although Dwinnell Dam is the most important diversion structure on the Shasta River, numerous other diversions have an important but unquantified effect. Many of the structures create low-water migration barriers and during summer create water-quality problems by acting as thermal and nutrient traps. Unscreened diversions have been identified as a serious problem for salmonid spawners, outmigrants, and juveniles (Chesney 2000).

Surface diversions and groundwater withdrawals have eliminated or substantially degraded flows on the Shasta River and its tributaries. The alterations are most evident during late spring through early fall, when increasing air temperatures and low flow coincide with poor water quality. The low flows also reduce habitat for salmonids and increase the adverse effects of diversion structures on migration.

Substantial reduction of flows by water withdrawal and the associated poor water quality probably are principal causes of decline in salmonid production in the Shasta watershed. The 1932 adjudication of surface waters in the basin, as currently administered, is insufficient to supply the quantity and quality of water necessary to sustain salmonid populations in the basin.

A major bottleneck for salmonid production in the Shasta River watershed is high water temperature (Figure 4-8). Daily minimum temperatures in the lower main stem in summer are typically greater than 20°C, and daily maximums often exceeding 25°C. Salmonids, especially coho salmon, rarely persist under such conditions. McCullough (1999) found that salmonids are typically absent from waters in which daily maximum temperatures regularly exceed 22-24°C for extended periods, although bioenergetic considerations or presence of thermal refugia may push distribution limits into slightly warmer water (see Chapter 7). Growth and survival are usually highest when temperatures stay within an optimal temperature range; this range differs among species and life-history stages, but for juvenile salmonids in the Klamath system, optimal temperatures are 12-18°C (Moyle 2002); bioenergetic considerations also alter optimal temperatures for growth and survival (McCullough 1999). The Shasta River becomes progressively cooler as elevation and flows increase, but temperatures remain largely suboptimal for salmonids for most of its length from late June through early September (Figure 4-8). Higher temperatures also are associated with reduced amounts of dissolved oxygen (DO) in the water. DO concentrations below saturation are apparently uncommon in the Shasta River, but where they occur, they coincide with high temperatures and low flows (Campbell 1995, Gwynne 1993). The causes of high temperatures include chronic low flow due to agricultural diversions, lack of riparian shading, and addition of warm irrigation tailwater. Temperature simulations for the Shasta River conducted by Abbott (2002) demonstrate the importance of flow and riparian vegetation to river temperatures (Figure 4-9). Low flows with long transit times typical of those now occurring in the summer on the Shasta River cause rapid equilibration of water with air temperatures, which produces water temperatures exceeding acute and chronic thresholds for salmonids well above the mouth of the river. Small increases in flow could reduce transit time substantially and thus increase the area of the river that maintains tolerable temperatures. Increases in riparian vegetation also could help to sustain lower water temperatures. Unlike other large tributaries, the Shasta River has a relatively narrow channel that could be strongly affected by riparian shading. Simulations of the effect of mature riparian forests for weather conditions of August 2001, and in drought conditions, showed lowering of daily mean water temperature at the mouth of the river from 21.4°C to 17.1°C and lowering of average maximum temperatures from 31.2°C to 24.2°C (Abbott 2002).

THE SCOTT RIVER (RM 143)

The watershed of the Scott River historically has provided important spawning and rearing habitat for coho salmon and, on the basis of records of spawning runs as recent as winter 2001-2002 (USFWS 2002), remains one of the most important tributary watersheds for coho in the lower Klamath basin.

The hydrology and water budget of the Scott River watershed are poorly documented. One USGS gage at Fort Jones provides the longest continuous record of flows (1942-2002). The gage is 16 mi upstream of the Klamath River and does not take into account accretions from the tributaries to the Scott River Canyon. Mean annual runoff within the basin is 489,800 acre-ft (range 54,200-1,083,000 acre-ft). Flows within the tributaries are poorly documented.

The hydrograph of the Scott River, like that of the Salmon River, shows two seasonal pulses (Figure 4-10) that are unaffected by any large impoundments. The winter pulse is caused by high precipitation from mid-December through early March and is highly important geomorphically because it accounts for most of the annual sediment transport (Sommerstram et

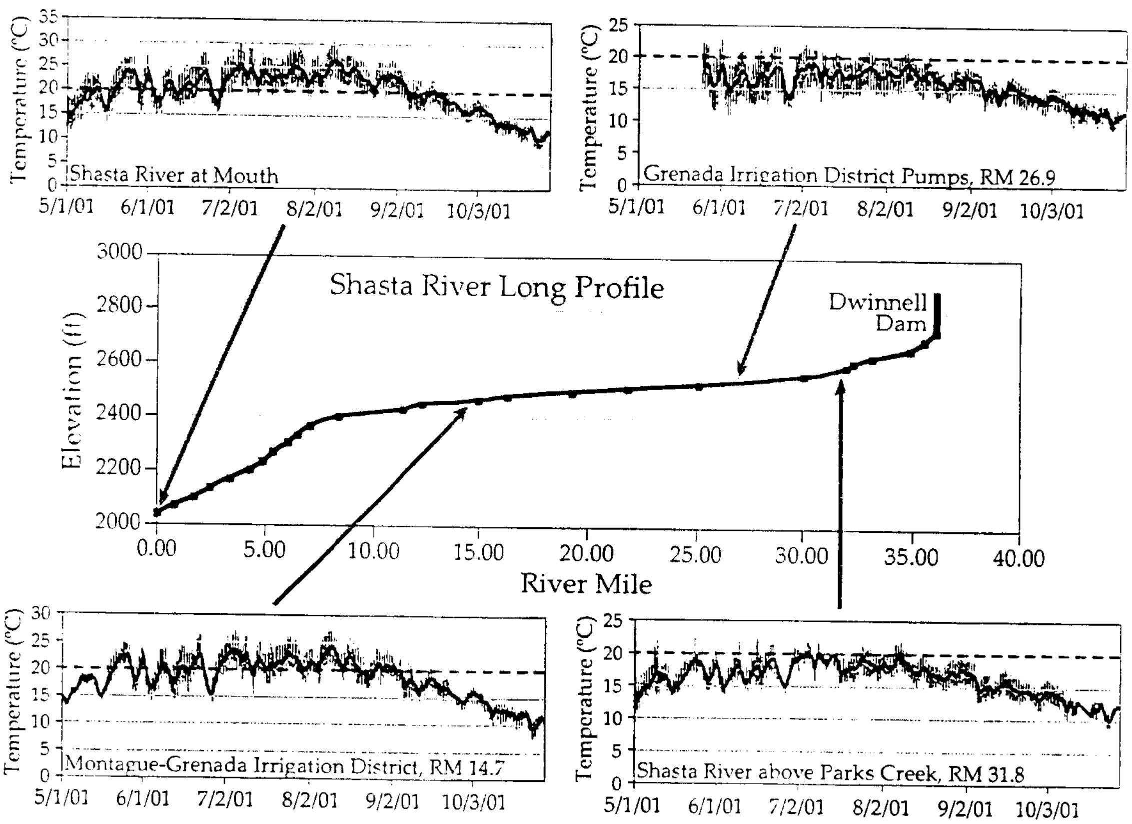


Figure 4-8. Temperature (thin line) and daily average temperature (wide line) within the Shasta River below Dwinnell Dam during the summer of 2001. The dashed line at 20°C is for comparison between plots. Note that the generally cool, spring-fed upper reaches of the river have temperatures suitable for salmon. Low flow, warm tailwater return flows, and lack of riparian cover on the lower main stem lead to high temperatures unsuitable for salmonids. Source: Abbott 2002, permission pending.

al. 1990, Mount 1995). The second pulse is caused by the spring snowmelt, which begins in late March and in wet years continues through June (Figure 4-10).

From late June through November, flows in the Scott River and its tributaries are low (Figure 4-10). During average to dry years, the tributaries with large alluvial fans are disconnected from the Scott River except through subsurface flow (Mack 1958, CSWRCB 1975). The loss of flow is caused by high seepage in the alluvial fans and diversions for irrigation. Along the main stem of the Scott River, surface flow ceases in several reaches during August and September of average and dry years. Discontinuous flow occurs into the fall. During average and wet years, continuity of flow is restored between late October and early November as evapotranspiration declines and irrigation decreases. During dry years, low-flow conditions persist until substantial rainfall occurs. Unlike the Shasta River, the Scott River shows lack of significant recovery of base flow during late fall and winter in years of low rainfall, indicating lack of resiliency in the groundwater reservoirs.

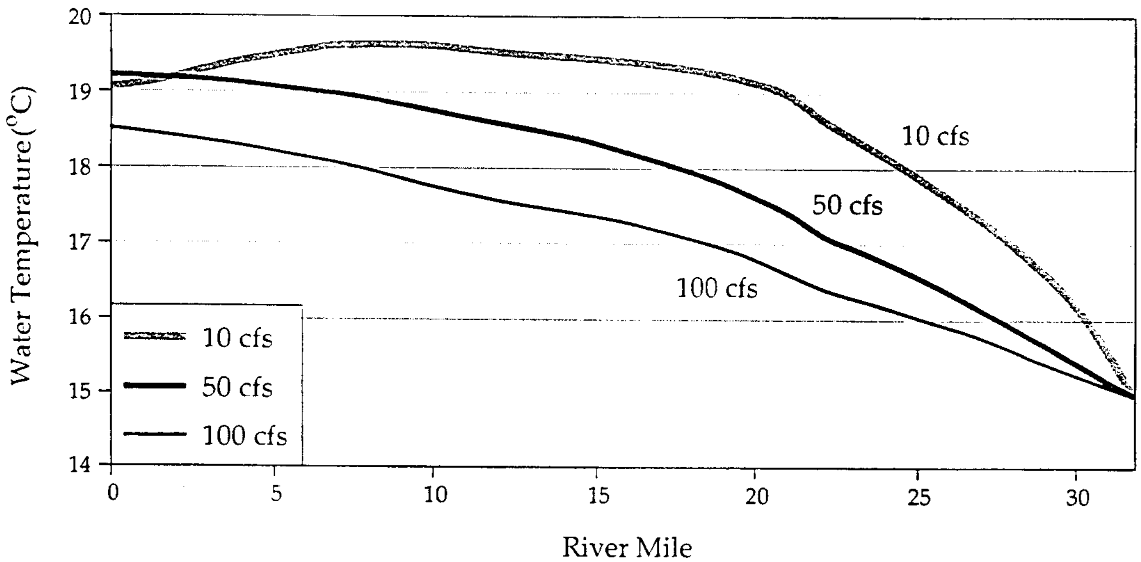


Figure 4-9. Simulation of daily mean water temperatures in the Shasta River at three flows with assumption of full restoration of riparian canopy (characteristic August conditions). Source: Abbott 2002, permission pending.

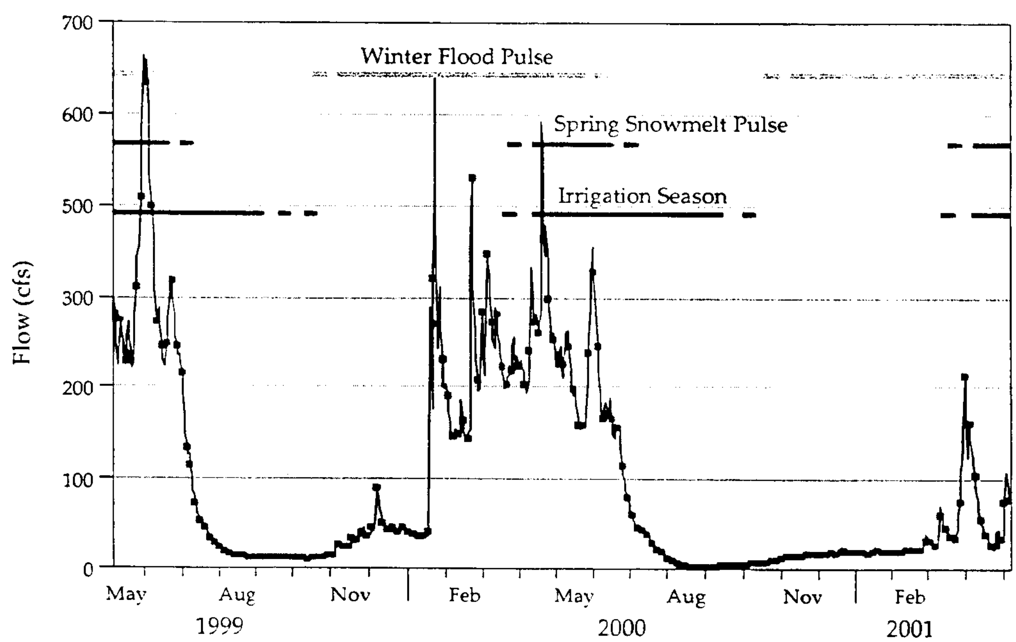


Figure 4-10. Annual hydrograph of Scott River at Fort Jones, California, May 1999 through May 2001. Note the significant decline in flows at the start of the irrigation season and weak recovery of flows during the dry winter of 2000-2001.

Because low base flow during summer and early fall is a natural element of the Scott River hydropattern, dry conditions in some reaches of the river may have occurred at some times before water management. Water management has decreased fall flows and has increased the frequency and duration of negligible flow.

The main groundwater source for irrigation and domestic water use in the Scott valley is the extensive alluvium under the river (Mack 1958, CDWR 1965). High rates of recharge to the valley aquifer, whose volume exceeds 400,000 acre-ft, are a byproduct of the fan heads of west-side tributaries, which receive seepage through the river bed; direct recharge from seepage of precipitation; infiltration losses from irrigation ditches; and deep percolation of irrigation water.

Groundwater levels in the valley aquifer reflect drawdown during the irrigation season and recharge during the wet season. The combination of high specific capacity of the shallow alluvial aquifers of the basin and high hydraulic gradients produces rapid seasonal changes in groundwater levels. Where subsurface water-bearing sediments are hydraulically connected in the Scott Valley, groundwater pumping can cause serious losses in channel flow (Mack 1958, CSWRCB 1975). Thus, pumping may be an important contributor to low-flow and no-flow conditions. There has been no comprehensive analysis of the water budget of the Scott River.

The Scott River and most of its tributaries are adjudicated under California water law. Adjudication and enforcement play key roles in the water budget of the Scott River. The Scott Valley Irrigation District initiated adjudication proceedings by petition to the California State Water Resources Control Board (CSWRCB) in 1970. Investigations cited above revealed the hydraulic connections between shallow groundwater and surface flows, indicating that adjudication should include both surface-flow rights and pumping rights adjacent to the river. At the time, this type of adjudication was not allowed under California statutes. Special legislation was developed for the innovative adjudication of the Scott River. Most of the shallow ground water in the valley probably is linked to the surface flows. Recognizing this, the CSWRCB staff arbitrarily chose an adjudicated zone extending about 1000 ft from the mainstem channel of the Scott River (CSWRCB 1975).

In 1980, the Siskiyou County courts decreed the Scott River adjudication, recognizing 680 diversions capable of diverting up to 894 cfs from the river and its tributaries above the USGS gage at Fort Jones (CH2M HILL 1985). Adjudications had been completed earlier on Shackleford and Mill creeks and on French Creek. Since 1989, the Scott River and its tributaries French, Kidder, Shackleford, and Mill creeks have been considered fully appropriated by CSWRCB.

The CDWR has provided a watermaster service to minimize litigation over water rights. Although a watermaster oversees 102 decreed water rights on several tributaries in the basin, no watermaster service has been requested for the main stem.

During the adjudication process, the state and federal governments both failed to negotiate successfully for water that would favor robust populations of fish. There are now no adjudicated rights for fish upstream of the USGS gage in Fort Jones. Below the Fort Jones gage, the U.S. Forest Service (USFS) was allotted flow of 30 cfs during August and September, 40 cfs during October, and 200 cfs from November through March to protect fish. With no watermaster service, USFS, a junior appropriator, commonly does not receive its adjudicated flows during late summer and fall.

Assessments of limiting factors for coho salmon have been summarized by Siskiyou County Resource Conservation District (Scott River Watershed CRMP Council 1997, West et al. 1990) and are given in Chapter 8. The limiting factors can be grouped into two classes: those associated with tributary flows and conditions, and those associated with the main stem of the Scott River.

Tributaries that drain the west side of the watershed and the East and South Forks of the Scott have substantial habitat for coho and other salmonids. Juvenile salmon occupy the uppermost reaches of the tributaries, where they benefit from the consistently low water temperatures and perennial flows (West et al. 1990). West-side tributary reaches that are above the major diversions maintain high water quality and favorable temperatures throughout the year, including August and early September (SRCD 2001). Maximum weekly average temperatures range from 15 to 17°C, and diel fluctuations are less than 3°C.

The principal limiting factor in the upper tributary reaches is excessive sediment derived from logging, particularly in tributaries with granitic soils (CH2M HILL 1985, Lewis 1992). Highly erodible decomposed granite has led to a serious loss in volume and number of pools in tributaries and associated degradation of spawning and rearing habitat. Logging over the past 50 yr has taken place on a mix of USFS land and land held by a few large private timber companies. Historical logging practices have been poor, particularly on private land, and have left a legacy of degraded hillslope and stream conditions.

Within the lower reaches of the west side, where tributaries contain surface diversions or large alluvial fans, low or negligible flow may be a limiting factor for coho and other salmonids. The loss of base flow in these tributaries may have occurred historically during dry years, particularly where there were large alluvial fans. Diversions and groundwater withdrawal, however, probably have increased the frequency and length of dry conditions, particularly in Etna, Patterson, Kidder, Mill, and Shackleford creeks (Mack 1958). The dewatering of these tributaries eliminates potential rearing habitat for coho and causes loss of connectivity and reduction of base flow in the main stem. Dry conditions in these creeks can persist into fall, thus blocking tributary access for spawning coho, steelhead, and Chinook.

West et al. (1990) documented 128 mi of potential spawning and rearing habitat for coho in the Scott River, mostly on the main stem. Degradation of habitat, however, is considerable; less than 30% is rated good to fair (SRCD 2001). California Department of Fish and Game (1999) rated the holdover of adults before spawning as fair, spawning habitat as fair, and juvenile rearing habitat as poor. The decline in salmonid habitat conditions on the main stem of the Scott is caused by channel alterations, low flow, and poor water quality.

The mainstem channel of the Scott River has been extensively altered over the last 150 yr by placer and hydraulic mining, logging, grazing in the riparian corridor, unscreened irrigation and stockwater diversions, elimination of wetlands, and flood-management or bank-stabilization efforts. These activities have cumulatively degraded salmonid habitat on most reaches of the main stem above the canyon. The most important limitations appear to arise from loss of optimal channel complexity and depth, loss of riparian vegetation, and unscreened diversions. There are 153 registered diversions in the Scott Valley, of which 127 are listed as active by SRCD. Fish screens have been installed on 65 of these diversions; another 38 are funded but not yet built (SRCD 2001).

Seasonal low flows are consistently recognized as one of the most important limiting factors for all salmonids that use the main stem of the Scott River (CH2M HILL 1985, West et al. 1990, SRCD 2001). Low flows and dry conditions contribute to the decline in spawning and rearing habitat in the river and exacerbate poor water quality during summer and early fall. During years when seasonal rains arrive late, low-flow conditions can persist into the fall, and limit access of salmon to spawning sites in tributary streams.

Low-flow and dry conditions are a natural aspect of the mainstem Scott in dry years, but the adjudication of the Scott River and its tributaries offers little protection for stream flow and related temperature requirements of salmonids in the watershed even during normal years. The adjudicated water rights are sufficient to allow removal of all flow from the river during the summer and early fall. The shift from surface diversions, which are naturally self-limiting, to groundwater wells, has exacerbated the apparent overappropriation of water in the watershed. That problem is compounded by a limited watermaster service in the basin and insufficient records, so it is not known whether diverters are adhering to their appropriative rights. The net result is that limited management and overappropriated water have seriously affected flows in the river.

The frequency and duration of low-flow conditions has increased since the 1970s (summary in Drake et al. 2000); the most important effects occur in September (Figure 4-11A), as confirmed by analysis of double-mass curves that compare runoff between the Scott River and the nearby Salmon River, which is not subject to diversion (Figure 4-11B). The decline in late summer and fall runoff is a considerable challenge to restoration of salmonid holding, spawning, and rearing conditions in the Scott River. In the absence of credible information and hydrologic models, there has been widespread speculation about the causes of declining flows in the Scott River. For example, Drake et al. (2000) postulated that the principal cause of declining late summer and fall flows in the Scott River is climate change. Drake et al. analyzed the relationship between precipitation in the Scott River watershed and fall runoff. Their work demonstrated a modest statistical correlation between declining precipitation in April at two snowpillows (snow-accumulation sensors) in the western edge of the watershed and declining runoff in September. On the basis of that correlation, Drake et al. (2000) ascribed the fall runoff shifts to declines in the water content of the April snowpack caused by climate change. They concluded that changes in land-use practices and water use were not responsible for declining flows.

The analysis by Drake et al. correlated fall flows only to two snow gages that showed declines in April snowpack. Five other gages in the basin showed no long-term changes in precipitation. As Power (2001) noted, the two stations that Drake et al. used are also invalid for comparative purposes because encroachment of forest vegetation has progressively reduced the catch of the snowpillows since their installation. Thus, it remains likely that the decline in fall flows can be attributed to changes in land cover and water-management practices in the watershed.

Cropping patterns in the Scott River valley have changed during the last 50 years (Figure 4-12A). In 1953, there were 15,000 acres of irrigated agriculture and 15,000 acres of natural subirrigation in the Scott valley (Mack 1958). Land surveys (CDWR 1965; CDWR, Red Bluff, CA, unpublished material, 1993) show that the amount of irrigated land has not changed substantially since 1953, but land use has. Grain declined from 7000 acres in 1953 to 2000 acres

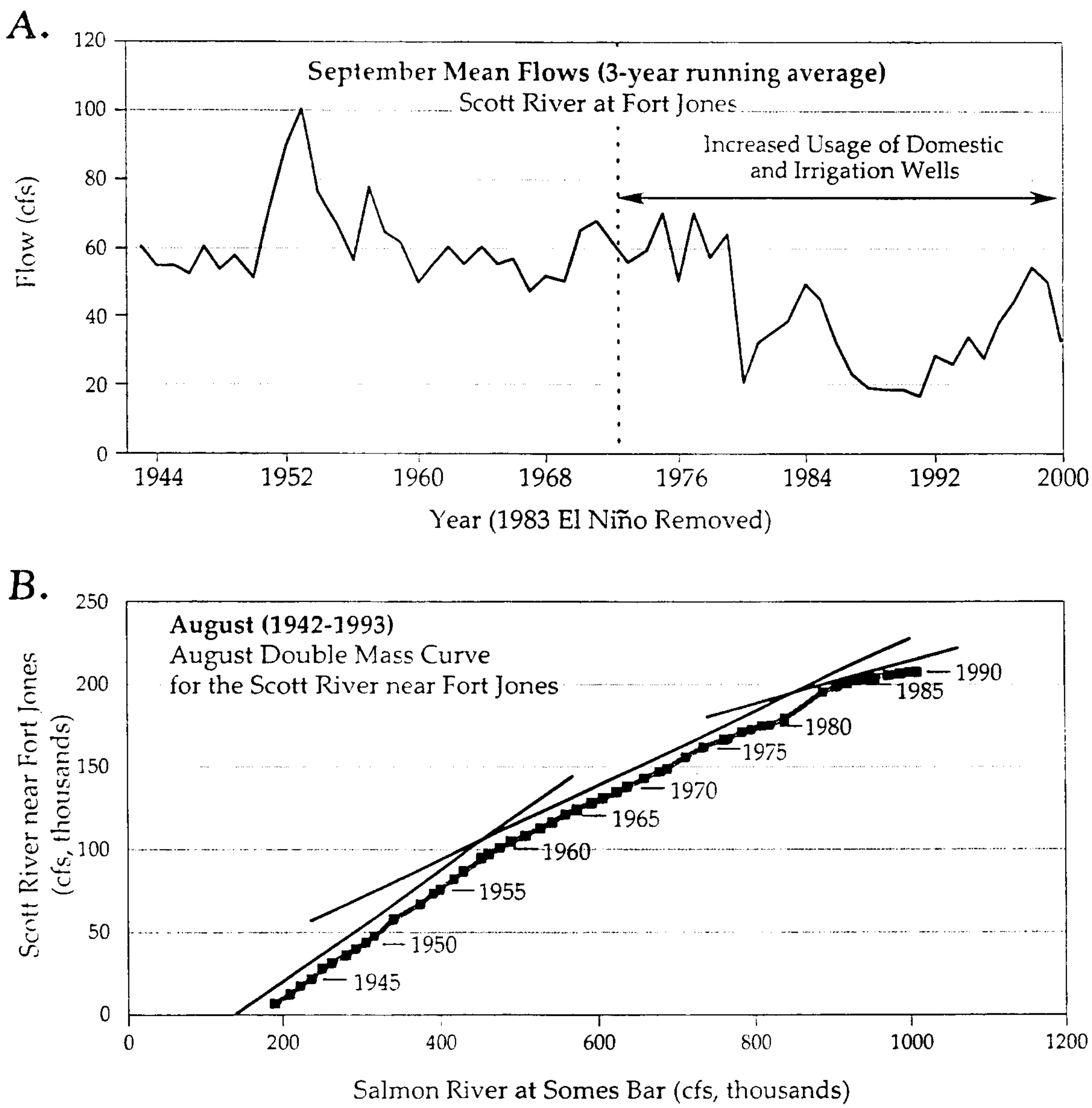
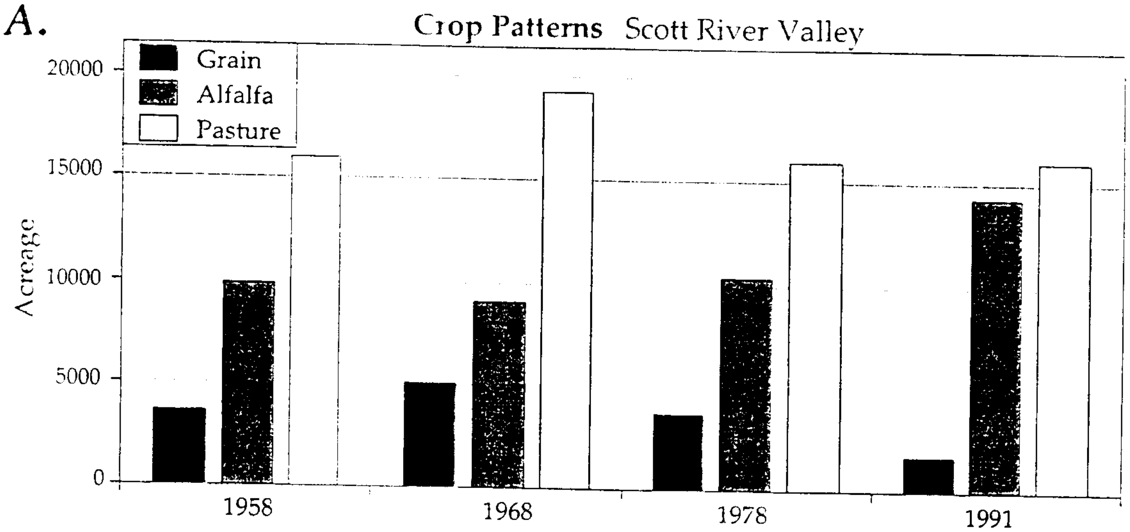


Figure 4-11. Declines in late summer and early fall flows on the Scott River. A) 3-yr running average of September mean flows, 1942-2002. Note the shift in low-flow conditions in late 1970s. B) Double-mass curve of August flow volumes on the Scott vs the Salmon River showing decline in August volume in the Scott relative to the Salmon during last 50 yr. Source: Bartholow 1995.

in 1991; alfalfa increased by 40% from 10,000 acres to more than 14,000 acres. Alfalfa has evapotranspiration rates that are several times greater than those of grain. Increased cultivation

A.



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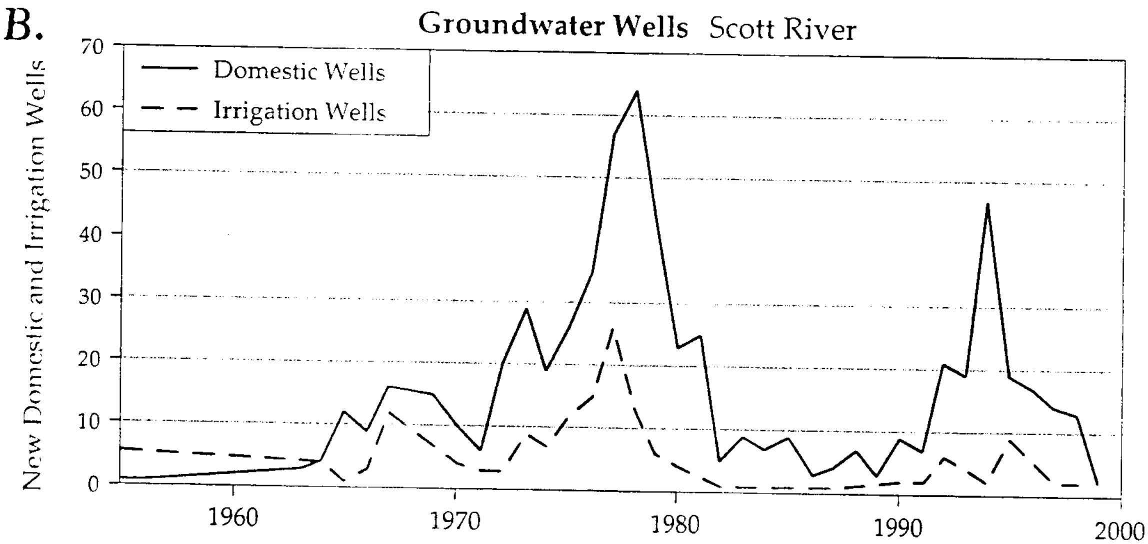

Figure 4-12. Changes in cropping and water wells in the Scott Valley. A) Increase in alfalfa production from 1958 to 1991. Sources: citations in text. B) New domestic and irrigation wells recorded in the Scott Valley from 1954 to 1999, showing increase in well-drilling activity in the 1970s. Source: data from CDWR records, provided by K. Maurer.

of alfalfa, including a tendency to seek four cuttings per year (SRCD records) rather than the traditional three, may have caused a decline in fall flows.

The change in cropping patterns is mirrored by a shift from surface diversions to irrigation wells (Figure 4-12B). CDWR records of well drilling in the Scott valley indicate a large increase in irrigation and domestic wells during the 1970s and 1990s. During the 1950s, there were about 60 domestic wells and six irrigation wells in the valley. During the 1970s, more than 300 domestic wells and 100 irrigation wells were drilled in the valley. That shift from surface diversions to wells increased the amount and reliability of water for irrigation. Because of the high specific capacity of shallow aquifers in the Scott basin, pumping also decreased the contribution of shallow ground water to base flow in the Scott River.

Water temperatures of the Scott River in July through September exceed thresholds for chronic and acute stress of coho and other salmonids (Figure 4-13). Ambient air temperature is the primary control on maximum weekly average temperature (MWAT)—warmest 7-day period for 1995-2000—of the main stem during summer and early fall (SRCD 2001).

MWAT increases downstream along the main stem of the Scott River because of the long hydraulic residence time of summer flow (Figure 4-13). Local cooling of mainstem temperatures is associated with augmentation of baseflow by shallow ground water. Local warming of the Scott is associated with reaches of the river where water loss and tailwater return flows occur, but the current monitoring program is not capable of resolving heat flux.

Dissolved oxygen of the Scott River has been monitored sporadically. Dissolved-oxygen data are available from 1967 to 1979 at Ft. Jones (Earthinfo, Inc. 1995) and from 1961 to 1967 and 1984 (CDWR 1986). The lowest concentrations of oxygen occur during late August and early September, when flows are low and temperatures are high. The data suggest that problems with low concentrations of dissolved oxygen, if any, are limited temporally and spatially.

Extensive, locally-driven efforts are underway in the Scott Valley to address the decline in water quality, and in salmonid spawning and rearing habitat. These efforts are led by the SRCD and the local Watershed Council, with cooperation from state and federal agencies, and have been well funded through aggressive grant acquisitions. Only a handful of these efforts have monitoring programs that allow assessment of their effectiveness, and there appears to be no independent review of the restoration and monitoring programs. More importantly, these efforts have yet to address comprehensively water budgets and water uses, including the contribution of ground water to surface flows and water quality. Until a comprehensive water budget is developed, significant progress at restoring coho and other salmonids is unlikely to occur.

THE SALMON RIVER (RM 62)

Within the lower Klamath watershed, the Salmon River remains the most pristine tributary; it has a natural, unregulated hydrograph, no significant diversions, and limited agricultural activity. Although it is not well documented, runs of all the remaining anadromous fishes in the Klamath watershed (Chapter 7, Table 7-1) occur in the Salmon River (Moyle et al. 1995, Moyle 2002).

The Salmon River's unique characteristics stem from its mountainous terrain and public ownership of land. At 750 mi^2, the Salmon River is the smallest of the four major tributary watersheds in the Klamath basin. Even so, the annual runoff from the Salmon is twice that of the Scott and 10 times as great as that of the Shasta River. High runoff reflects the steep slopes and high annual precipitation (50 in) of the watershed. Runoff in the basin is dominated by a winter pulse associated with high rainfall and a spring snowmelt pulse from April through June (Figure 4-14). During summer and late fall, low-flow conditions predominate, particularly in smaller

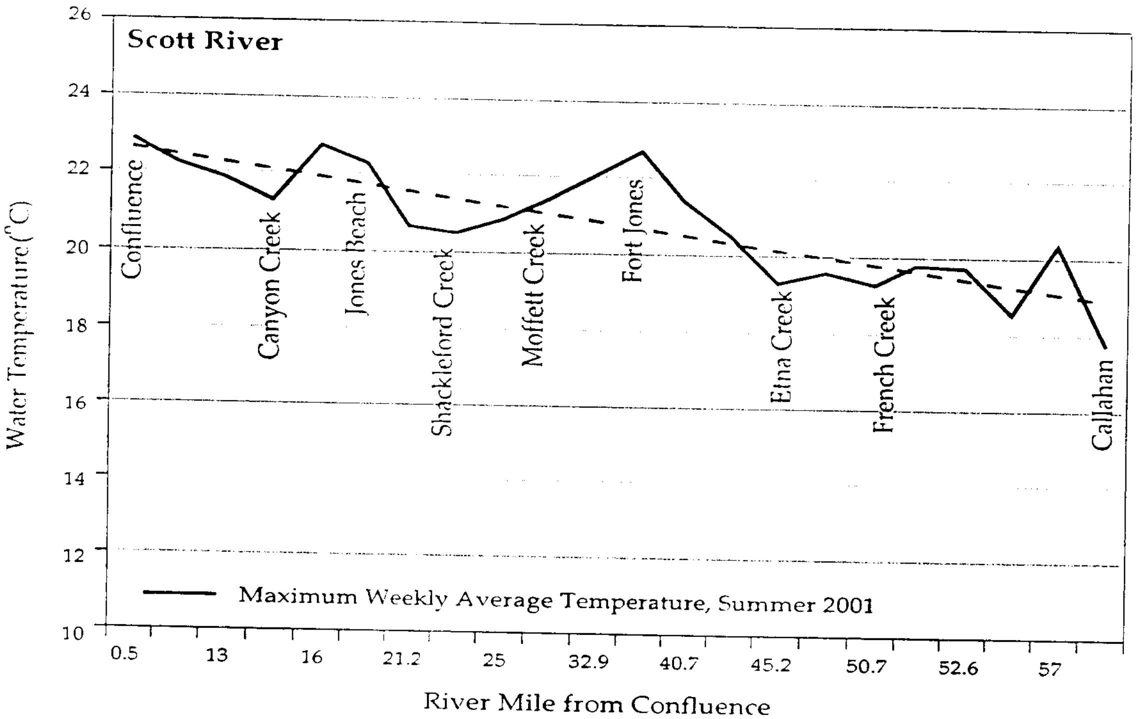

Figure 4-13. Plot of downstream changes in maximum weekly average water temperature on the main stem of the Scott River during summer. Note the irregular pattern of change in temperature, presumably associated with accretions from ground water and the effects of irrigation return flows. Source: modified from SRCD 2001.

tributaries. Unlike the Scott and Shasta, the Salmon River watershed is almost entirely federally owned (Chapter 2).

The Salmon River watershed supports about 140 mi of fall-run Chinook spawning and rearing habitat and 100 mi of coho and steelhead habitat (CDFG 1979a). Logging roads, road crossings, and frequent fires in the basin appear to contribute to high sediment yields. Historical and continuing placer mining has reduced riparian cover and disturbed spawning and holding sites in the basin as well. Increased water temperatures have been noted in the Salmon River during late-summer low-flow periods, but their cause is unclear; they may be natural or may be in part a byproduct of logging and fires. The high summer temperatures may also be in part a function of the orientation of the watershed and naturally low base flow during late summer (Kier and Associates 1998).

THE TRINITY RIVER (RM 43)

The Trinity River has the largest tributary watershed in the lower Klamath basin (2900 mi^2). The watershed extends up to 9000 ft in the Trinity Alps and the Coast Ranges and flows

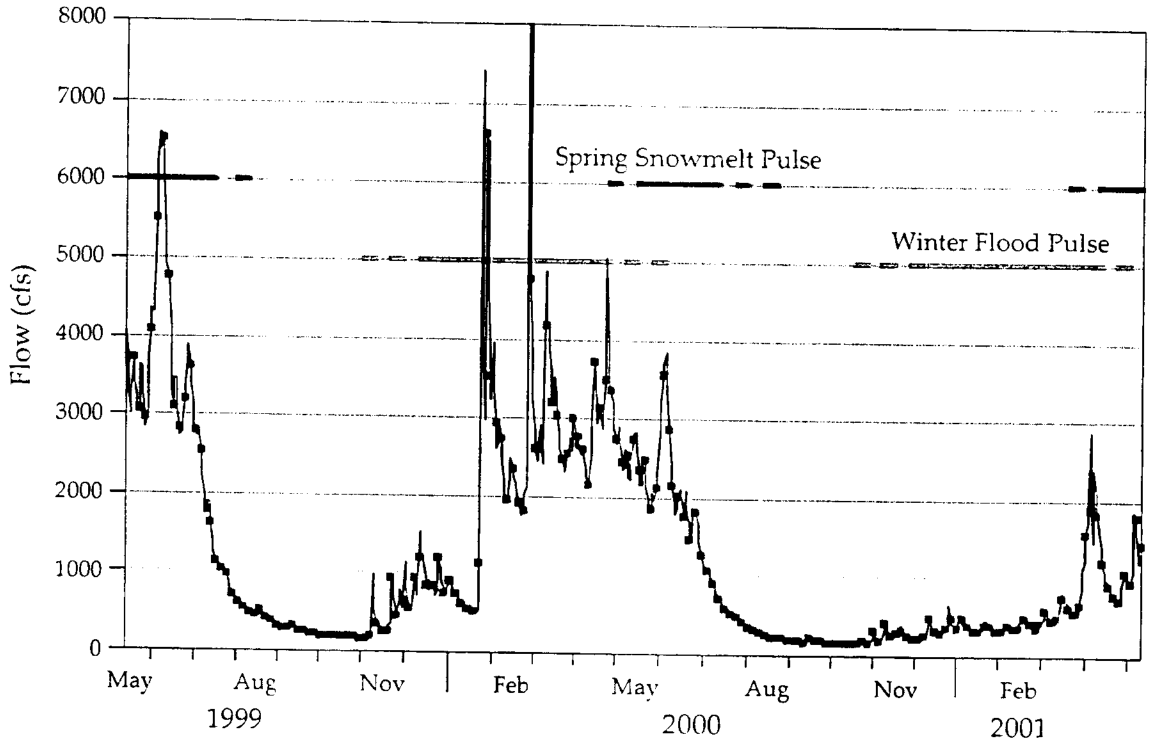

Figure 4-14. Annual hydrograph of the Salmon River at Somes Bar, California, May 1999-May 2001.

more than 127 mi to its confluence with the Klamath at 230 ft asl, 43 mi above the Klamath River mouth (Figure 4-15). It is the largest contributor of tributary flow to the mainstem Klamath. Prior to construction of the Trinity River Diversion (TRD), the Trinity River accounted for close to one-third of the average total runoff from the Klamath watershed (based on USGS gauging records)—more than twice the runoff from the entire upper basin.

Hydrologically, the Trinity watershed is broadly similar to the Scott and Salmon watersheds. Prior to construction of the Trinity River Diversion (TRD) project in 1963 (discussed below), runoff averaged close to 4.5 MAF annually. The bulk of this runoff was concentrated into two seasonal pulses (Figure 4-16)—winter floods associated with mixed rain-snow events that typically occur between mid-December and mid-March, and a spring snowmelt pulse that begins in late March-early April and, depending upon snowpack conditions, ceases in July. The summer and fall are dominated by baseflow conditions. Historically, late summer and early fall flows on the Trinity were quite low, indicating limited natural baseflow support. During years of below-average moisture, tributaries to the Trinity commonly dry up.

Precipitation patterns and associated runoff vary considerably throughout the Trinity watershed. Precipitation averages 57 in. annually, but approaches nearly 85 in. in the Hoopa Mountains and the Trinity Alps. In the high-altitude, northeastern portions of the watershed, the annual hydrograph is dominated by snowmelt runoff during the spring and early summer. In

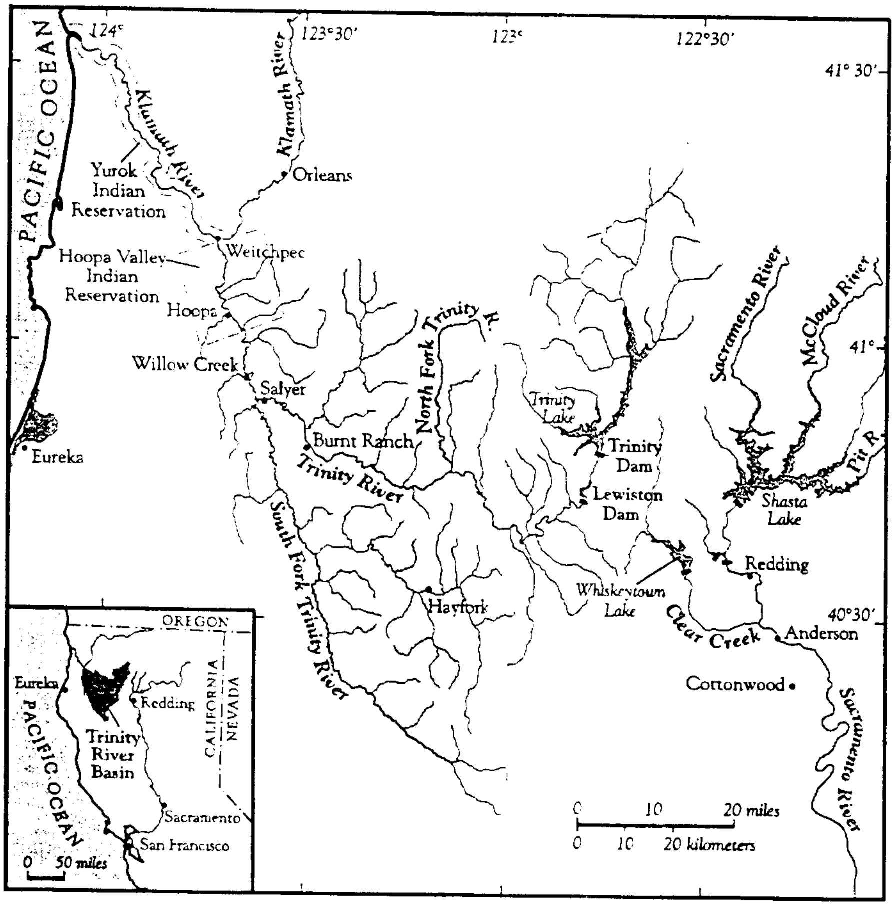

Figure 4-15. Index map of the Trinity River watershed. Source: modified from USFWS/HVT 1999.

contrast, the lower-elevation watersheds, such as the South Fork and North Fork, are dominated by winter rainfall flood pulses.

As noted in Chapter 2, the tectonic, geologic, and climatic setting of the Trinity River has amplified the influence of land-use activities on fish. Highly unstable rock types, which are associated with the Coast Range Geologic Province on the west and the Klamath Mountains Geologic Province on the east, coupled with high rates of uplift, lead to naturally high erosion rates (Mount 1995). Like the western portions of the Scott watershed, the eastern portions of the Trinity watershed contain deeply weathered granitic rocks that yield highly erodible soils dominated by decomposed granite. In both the eastern and western portions of the watershed, highly unstable metamorphic rock units are associated with numerous and widespread slope failures. Landslides play a dominant role in hillslope evolution on the South Fork Trinity and in canyon reaches of the main stem.

Approximately 80% of the Trinity watershed is federally owned and is managed by USBR and USFS. The remainder is a mix of private ownership and lands within the Hoopa

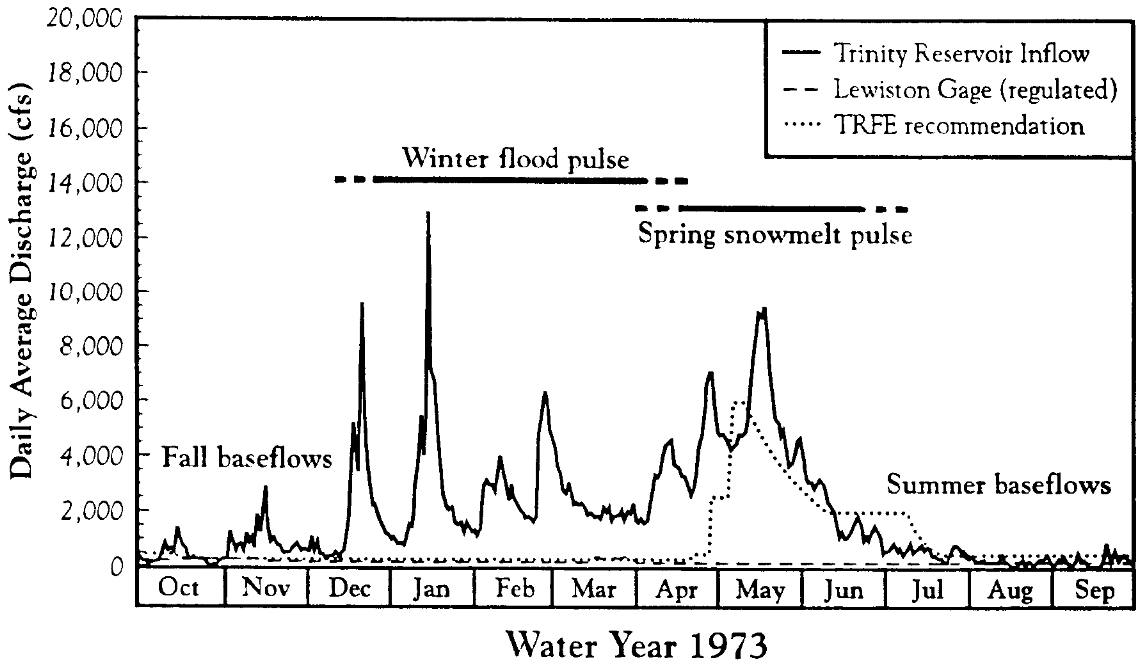

Figure 4-16. Example of regulated (dotted line, current recommended outflow) and unimpaired (solid line, inflow to Trinity Diversion Project) flows on the Upper Trinity River for water year 1973, a normal water year (40-60% exceedance probability for annual flow volume). Source: modified from USFWS/HVT 1999.

Valley and Yurok Indian reservations. Land-use practices on public and private land within the Trinity watershed have played a central role in the precipitous decline of salmon runs in the latter half of the 20th century.

As with most tributary watersheds of the Klamath system, logging, mining, and grazing have reduced the quantity and quality of salmon habitat in the Trinity watershed. The greatest effects have occurred in the South Fork of the Trinity and on the main stem below Lewiston Dam and above the confluence of the main stem with the North Fork.

The South Fork is the largest tributary of the Trinity River, and was historically a significant producer of Chinook and coho salmon and steelhead trout (Pacific Watershed Associates 1994). The South Fork and its main tributary, Hayfork Creek, comprise 31% of the Trinity watershed and 6% of the total Klamath watershed. The South Fork, which is undammed, is the largest unregulated watershed in California. Currently, more than 56 mi of the river are protected under the California Wild and Scenic Rivers Act.

The South Fork has high background sedimentation rates, but intense logging in the 1960s on highly unstable soils, coupled with a large storm in 1964, produced sedimentation rates significantly above background levels. Adverse effects of sediment on aquatic life caused EPA to require a total maximum daily load (TMDL) study for sediment in the South Fork (EPA 1998). Loss of riparian cover and deep pools also appears to have affected water temperature.

Most regional and national attention has been focused on the main stem of the Trinity River. Mining, logging, and grazing practices within this portion of the watershed contributed high volumes of sediment to the main stem and degraded habitat prior to creation of the TRD (EPA 2001). Logging on sensitive soils produced high loads of fine sediment in the mainstem Trinity. Prior to TRD operations, however, seasonal high flows associated with the winter and spring flood pulses appear to have maintained habitat of reasonable quality, thus preventing a significant decline in steelhead and salmon (McBain and Trush 1997).

In 1955 Congress authorized construction of the TRD project to divert water from the upper Trinity River into the Sacramento River as part of the Central Valley Project (CVP). The primary beneficiaries of these diversions are farms of the San Joaquin Valley serviced by the Westlands Water District. The TRD consists of two dams: the Trinity Dam, which has an impoundment capacity of 2.4 MAF, and Lewiston Dam, which impounds Lewiston Reservoir and provides the diversion for the CVP.

The closure of Lewiston Dam in 1963 led to loss of access to spawning sites and degradation of habitat. Located at Trinity RM 112, Lewiston Dam currently blocks access to more than 109 mi of potential spawning habitat in the upper watershed (USFWS 1994). Additionally, the Trinity and Lewiston Dams trap all coarse sediment that would normally be supplied by the upper watershed.

When completed, the TRD diverted more than 88% of the annual runoff from the upper watershed to the CVP. After 1979, these diversions were decreased to 70% of the annual runoff. The magnitude of the diversions and associated flow release schedules eliminated winter and spring flood pulses in the main stem of the Trinity (Figure 4-16). The effects of these manipulations are most acute between Lewiston Dam and the North Fork Trinity (RM 112-72). Below the North Fork, tributary flow and sediment supply reduce the adverse effects of upstream water management (USFWS/HVT 1999).

Changes in hydrology on the Trinity River, loss of sources of coarse sediment, and continued influx of fine sediment from hillslope erosion have created significant changes in habitat conditions downstream of the TRD. Channel response to changes in flow regime included reductions in cross section, reduction in lateral migration, establishment of riparian vegetation on channel berms, loss of backwater habitat, and loss of spawning gravel. The new channels have been static, reduced in size, and deficient in suitable habitat.

In 1981 the Secretary of the Interior authorized a Trinity River Flow Evaluation (TRFE) study of ways to restore the fishery resources of the Trinity River (USFWS/HVT 1999). The final TRFE report recommends releases from TRD based on five water-yr types: extremely wet, wet, normal, dry, and critically dry. The hydrographs consistent with these recommendations still allow for delivery of water to the CVP, but shape the hydrographs so that they support the life-history needs of salmonids, including reintroducing disturbance to control establishment and growth of riparian vegetation, coarse sediment transport to establish pools and riffles and to clean spawning gravels, and sufficient flows to reduce water temperatures for rearing. The TRFE also contained an adaptive management approach that calls for assessment of the effect of changes in flow regime and adjustments as necessary to improve the success of the program.

The TRFE and the associated federal environmental impact statement (EIS) and environmental impact report (EIR) were the product of multiple years of collaborative effort on the part of agencies and stakeholder groups. This program was subjected to rigorous external peer review, which led to numerous, substantive revisions in proposed remediation measures. The TRFE was used in the Department of the Interior's Record of Decision (ROD; Trinity River Mainstem Fishery Restoration, USFWS 2000). A lawsuit filed by the Westlands Water District in 2001 contended, however, that the underlying studies did not adequately address the economic impacts of the CVP water on users and electricity consumers, and failed to account for the effects of changes in flow on ecosystems of the Sacrament-San Joaquin Delta. In 2001, U.S. District Court Judge Oliver Wanger ruled against the Department of the Interior (DOI) and ordered it to complete a supplemental EIS, which is still in preparation. Consequently, the recommended TRFE flow releases have not occurred. In response to the lower Klamath fish kill of September 2002, the presiding judge was asked by the Hoopa Valley Tribe to allow some operational flexibility in order to help avoid fish kills in September 2003. The judge allowed 50,000 acre-ft to be set aside for emergency increases in flow to reduce the chances of a fish kill. In August 2003, the Trinity Management Council requested that DOI allow a sustained flow release in September 2003 due to low-flow conditions and predictions of a large salmon run. As of September 2003, these modifications in flow were underway.

Given the size of the Trinity River watershed and its large amount of runoff, the operations of the TRD must affect the quality of habitat in the lowermost Klamath River and its estuary. There is little published information, however, on the effects of the Trinity on the lowermost Klamath and the estuary. Information provided here is principally derived from an analysis of USGS gaging data (1951-2002) from the Trinity and the Klamath, and from the Trinity River Flow Evaluation study (USFWS/HVT 1999).

Following construction of the TRD, the contribution of the Trinity to the total flow of the Klamath River declined from 32% to approximately 26% (Figure 4-17). This decline is not equally distributed throughout the year. The largest effect of the TRD occurs in the spring, during filling of the Trinity Reservoir. Prior to construction of the TRD, snowmelt runoff from the Trinity provided approximately 290,000 acre-ft, or approximately one-third of the inflow to the estuary, to the Klamath River in June. Following construction of the TRD, the average contribution of the Trinity in June declined to 160,000 acre-ft; during this same period, inflow to the Klamath estuary declined by approximately 200,000 acre-ft per yr.

During the late summer and early fall the Trinity, prior to construction of the TRD, contributed a relatively small amount to the total flow of the Klamath River (less than 15% in September). In the period following construction of the TRD, there was a decline of 11% in average September flow of the Klamath main stem above the Trinity. Because of minimum flow requirements for the TRD, however, average flows from the Trinity increased during this period, partially offsetting the declines in flow from Iron Gate Dam and boosting the Trinity's relative contribution to 20%.

Spring and early summer water temperatures are of concern in the lower Klamath and Trinity due to their effect on outmigrating steelhead and salmon smolts. Field and modeling studies conducted in 1992-1994 at the confluence of the Klamath and Trinity demonstrate the relative importance of flow to water temperatures (Appendix L in USFWS/HVT 1999). Although temperature differences between the Klamath and the Trinity River can be considerable (up to 5°C or more), temperature regimes usually are quite similar at the confluence because of the long distances of travel (> 100 mi) for water released from both Iron Gate Dam and Lewiston Dam, and the broadly similar release schedules of the two reservoirs. Differences

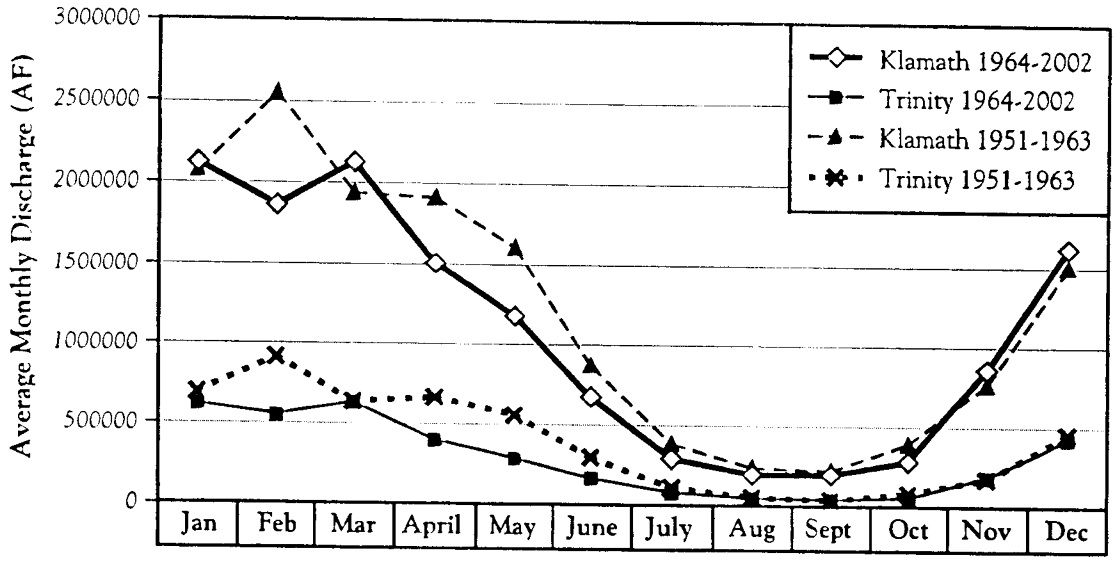

Figure 4-17. Average monthly discharge of the Klamath River at Klamath (USGS 11530500) and the Trinity River at Hoopa (USGS 11530000) for the period 1951-2002. The Trinity River Diversion project was constructed in 1963. Note the reduction in spring flows associated with operation of the TRD.

between the two rivers become pronounced only when there are large disparities in flow volumes. For example, when the Trinity flow releases are very large (by a factor of 2 to 3) compared to flow within the Klamath main stem, the Trinity cools the Klamath because its waters reach the confluence more quickly than at low flow.

The Trinity River Mainstem Fishery Restoration program (USFWS 2000) is, by necessity, focused principally on restoring spawning and rearing habitat within the mainstem Trinity River. Thus, from the viewpoint of coho recovery, the EIS process cannot be expected to result in the improvements of tributary habitat that coho require. Also, the program does not appear to have invested significant effort in evaluating its beneficial effects on the lower Klamath and its estuary. With the exception of the participation of the Hoopa Valley and Yurok Tribes, there also appears to be only minimal effort to coordinate management of the Trinity watershed with efforts to manage the rest of the Klamath watershed. The proposed flow release schedule contained within the 2001 ROD, which is currently held up in litigation, may, however, provide substantial benefit downstream of the Trinity, thereby increasing the welfare of salmon and steelhead throughout the Klamath watershed.

MINOR TRIBUTARIES TO THE LOWER KLAMATH MAIN STEM (RM 192-0)

Many small tributaries enter the mainstem Klamath between Iron Gate Dam and the mouth of the river. They drain mountainous, largely forested watersheds, but most are creeks affected to some degree by logging, past mining, grazing, and agriculture. In many of the tributaries along the stream corridors, water withdrawal leads to reductions in summer base flows. Water quality has not been extensively studied, but the tributaries may be particularly important in providing cold-water habitats for salmonids (Chapter 7). Of these creeks, 47 are known to have coho populations (NMFS 2002), but little is known about the specific conditions of these populations in relation to habitat and changing conditions in the basin.

In the more mountainous sections of the basin, slopes are steep, soils are unstable, and streams are affected by erosion that is exacerbated by roads and disturbance in the riparian zone. Large floods that have occurred about once per decade also have led to erosion, debris jams, and aggradation of sediments where tributaries enter the Klamath. In some cases, the bars, which consist of aggraded sediments, block flow during low-flow conditions, thus preventing fish passage, but many of the blockages have been removed in recent years (Anglin 1994).

MAINSTEM KLAMATH TO THE PACIFIC (RM 60-0)

Over its final 60 mi the Klamath flows first southwest from Orleans to Weitchipee, where the fourth major tributary, the Trinity River, enters at RM 43. The Klamath then flows northwest to the ocean. The estuarine portion of the Klamath River is relatively short in relation to the watershed. Because intrusion of salt water varies seasonally, the length of the estuary is variable. The greatest intrusions occur at low flow, but brackish water (15-30 ppt) extends only a few mi upriver even at low flow (Wallace and Collins 1997). Tidal amplitudes in the estuary vary up to 2 m.

Flows in the lowermost Klamath are driven by a seasonally varying mixture of mainstem flow and accretions of water from tributaries. For example, water reaching the river via the Iron Gate Dam contributes less than 20% of the flow at Orleans in May and June (1962-1991). The other 80% of the flow is derived primarily from tributaries. The percentage of flow that comes from Iron Gate Dam increases over the summer. In September, over 60% of the flow originates from Iron Gate Dam (Hydrosphere Data Products, Inc. 1993). As noted above, the Trinity River and operations of the TRD exert substantial influence over hydrologic conditions of the lower Klamath and its estuary. Changes in release, even under the new ROD, have led to declines in late winter through early summer flows at the mouth of the Klamath. Fall flows, on the other hand, are augmented by increased flows from the Trinity.

Although alteration of hydrographs in a number of headwaters and tributaries has been quite substantial (e.g., Lost River, Shasta River), the overall effect of water development on total annual flow of the downstream reaches of the Klamath River is surprisingly small. Runoff from the upper Klamath basin has been reduced from approximately 1.8 million acre-ft to 1.5 million acre-ft in a year of average moisture (USGS 1995, Hardly and Addley 2001, Balance Hydrologics 1996), and irrigation has depleted the mean annual flow at Orleans (above the Trinity), where the flow is approximately 6 million acre-ft, by less than 10%. There has been a noticeable shift in the timing of runoff, however. Peak annual runoff occurs in March instead of April and the flows of late spring and early summer tend to be lower than they were historically. In late summer, water temperatures at Orleans exceed 15°C typically from June into September (Figure 4-18). River temperatures in excess of 20°C occur on most dates in July and August and in many years, high temperatures extend into fall. For example, temperatures over 18°C have

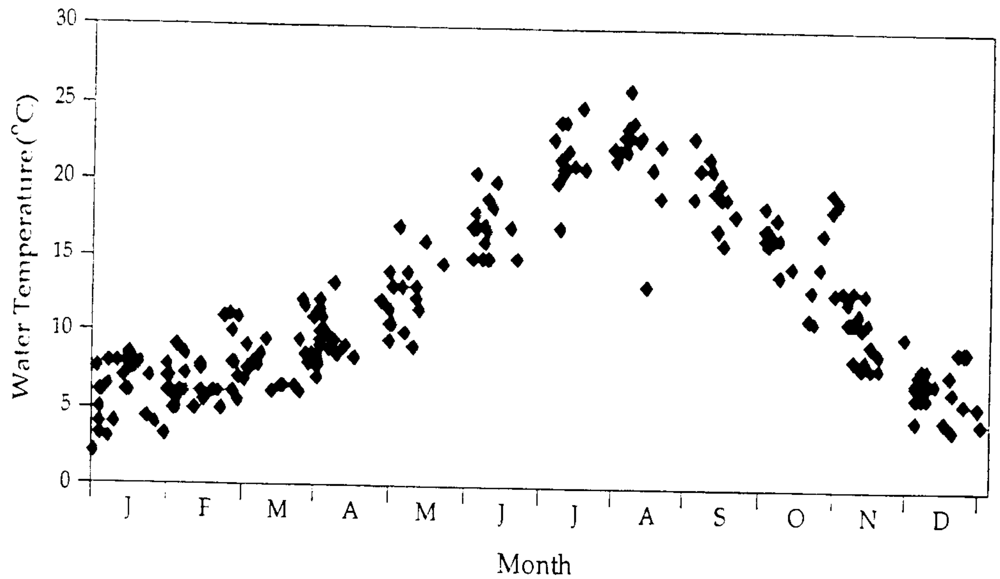

Figure 4-18. Water temperature (instantaneous daytime values) of the Klamath River at Orleans based on observations at USGS station 18010209, 1957-1980, plotted on a single annual time span.

been observed in late October. Temperatures in the Klamath may have always been high (over 15°C) in summer and fall, but it is likely that the loss of cold water from tributaries has resulted in a net increase in temperatures over the annual cycle, particularly during summer under either normal or low-flow conditions.

Even though hydrologic change in the lowermost Klamath main stem seems too small to have caused large changes in the estuary, significant impairment of the estuary could have occurred through warming of the river water and through increased organic loading caused by eutrophication and alteration of flow regimes in headwaters. The estuary could show adverse chemical conditions as a result of these changes, and coho in the estuary thus could be affected. The extent of these changes and their potential effect on coho have not been well documented, however. Information on water quality of the lowermost Klamath River is sparse.

CONCLUSIONS

Most flowing waters of the Klamath basin show substantial environmental degradation involving loss of coarse gravels, excessive suspended sediment, impaired channel morphology, loss of woody riparian vegetation, major alteration of natural hydrographic features, and excessive warmth. These changes affect not only the main stems of the Klamath River and major tributaries, but also small tributaries where salmon are or could be present. While to some extent historical, degradation continues through a variety of water-management and land-use practices including irrigation, grazing, mining, and timber management. Documentation is poor for some locations, and especially so for small tributaries.

In the upper basin, the tributaries that drain into Upper Klamath Lake are poorly understood except in regard to nutrient transport. Knowledge of basic hydrology and water use is sparse, as are conditions relevant to spawning of listed suckers and refugia for sucker fry. Topics of special interest include substrate and channel quality, sediment load, and status of riparian vegetation. In the lower basin, research has documented extensive modifications of riparian habitats, especially along the Scott and Shasta rivers. Adverse changes in stream-channel structure, sediment transport, flow, and temperature are commonplace even on federal lands.

Nutrients, dissolved oxygen, temperature, flows, and physical habitat of the main stem of the Klamath River have been extensively studied. Still, additional research that would clarify the interactions between hydrology and temperature, especially as affected by water-management strategies, is needed. Considerable research on this topic is in progress, but field investigations have focused primarily on the river between Iron Gate Dam and Orleans. Conditions in the lowermost reaches of the Klamath River, including the estuary, have received less attention but are important to salmonids, as shown by the mass mortality of salmonids in 2002 (Chapter 7).

The Klamath system as a whole is nutrient-rich and productive. High concentrations of phosphorus, a key nutrient, are typical of Klamath waters because of natural sources. Anthropogenic sources may be important in some cases as well. Water-quality conditions, except temperature, are within satisfactory bounds in most cases for flowing waters. The greatest impairments involve physical features, including temperature for salmonids.